Evaluating the Effectiveness of Temporary Work-Zone Pavement Marking Products

ctre
Center for Transportation Research and Education

Final Report
July 2012

SWZDI
Smart Work Zone Deployment Initiative

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Smart Work Zone Deployment Initiative
(TPF-5(081))
Federal Highway Administration
(InTrans Project 06-277)

About SWZDI

Iowa, Kansas, Missouri, and Nebraska created the Midwest States Smart Work Zone Deployment Initiative (SWZDI) in 1999 and Wisconsin joined in 2001. Through this pooled-fund study, researchers investigate better ways of controlling traffic through work zones. Their goal is to improve the safety and efficiency of traffic operations and highway work.

About CTRE

The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Disclaimer Notice

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the sponsors.

The sponsors assume no liability for the contents or use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The sponsors do not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Non-Discrimination Statement

Iowa State University does not discriminate on the basis of race, color, age, religion, national origin, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries can be directed to the Director of Equal Opportunity and Compliance, 3280 Beardshear Hall, (515) 294-7612.

Iowa Department of Transportation Statements

Federal and state laws prohibit employment and/or public accommodation discrimination on the basis of age, color, creed, disability, gender identity, national origin, pregnancy, race, religion, sex, sexual orientation or veteran's status. If you believe you have been discriminated against, please contact the Iowa Civil Rights Commission at 800-457-4416 or the Iowa Department of Transportation affirmative action officer. If you need accommodations because of a disability to access the Iowa Department of Transportation's services, contact the agency's affirmative action officer at 800-262-0003.

The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation or the U.S. Department of Transportation Federal Highway Administration.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
InTrans Project 06-277		

4. Title and Subtitle	5. Report Date
Smart Work Zone Deployment Initiative: Evaluating the Effectiveness of Temporary Work-Zone Pavement Marking Products	June 2012
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Neal Hawkins, Omar Smadi, and Basak Aldemir-Bektas	InTrans Project 06-277

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Research and Education Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664	**11. Contract or Grant No.**

12. Sponsoring Organization Name and Address		13. Type of Report and Period Covered
Midwest Smart Work Zone Deployment Initiative Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010	Federal Highway Administration U.S. Department of Transportation 1200 New Jersey Avenue SE Washington, DC 20590	Final Report
		14. Sponsoring Agency Code TPF-5(081)

15. Supplementary Notes

Visit www.intrans.iastate.edu for color PDF files of this and other research reports.

16. Abstract

Work zones by nature present transitions and changes to motorists' expectations. Given these conditions, providing proper guidance to motorists is critical.

With respect to pavement markings, the challenge is to provide sufficient markings but in a temporary setting. Various pavement-marking products are currently in use within work zones; however, their effectiveness and cost can vary widely.

This research evaluated the effectiveness of several common removable pavement marking products in terms of daytime presence, retroreflectivity, and removability. The evaluation was completed on an active work zone in central Iowa and included both white and yellow edge-line markings within the taper and crossover sections of a work zone.

Presence was evaluated in terms of the amount of product remaining at the end of the evaluation period. Retroreflectivity was measured using a 30 meter geometry retroreflectometer. Product removal was evaluated in terms of internal tape strength, adhesive bond, and the amount of discernible markings after removal based on the American Association of State Highway and Transportation Officials (AASHTO) National Transportation Product Evaluation Program (NTPEP).

Findings showed that the temporary pavement marking tapes performed satisfactorily over the 56 day time period with the exception of materials placed over very rough surfaces (rumble strip) or where vehicle maneuvering directly over the marking led to tearing or similar damage.

Based on these findings, the research team recommends that agencies who are not currently specifying the use of temporary pavement marking tape products on temporary roadway surfaces (eg. within the cross-over area of a work zone which will be removed after the project) should reconsider their policy. The cross-over area receives the majority of wear, due to traffic weaving, and these markings are placed over a variety of, smooth to very rough, pavement surface conditions. Removable paint products are rapidly evolving and are a potentially promising alternative in terms of installation, cost, and removal (no scaring) which should be further investigated.

17. Key Words	18. Distribution Statement
marking removal—marking retroreflectivity—removable paint markings—temporary pavement markings—work-zone markings	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	30	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

SMART WORK ZONE DEPLOYMENT INITIATIVE: EVALUATING THE EFFECTIVENESS OF TEMPORARY WORK-ZONE PAVEMENT MARKING PRODUCTS

Final Report
July 2012

Principal Investigator
Neal Hawkins, PE, Director
Center for Transportation Research and Education, Iowa State University

Omar Smadi, PhD, Research Scientist
Center for Transportation Research and Education, Iowa State University

Basak Aldemir-Bektas, PhD, Research Scientist
Center for Transportation Research and Education, Iowa State University

Authors
Neal Hawkins, Omar Smadi, and Basak Aldemir-Bektas

Sponsored by
the Midwest Smart Work Zone Deployment Initiative and
the Federal Highway Administration (FHWA)
FHWA Pooled Fund Study TPF-5(081): Iowa (lead state), Iowa, Kansas, Missouri, Nebraska, Wisconsin

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement with the
Institute for Transportation
(InTrans Project 06-277)

A report from
Center for Transportation Research and Education
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103
Fax: 515-294-0467
www.intrans.iastate.edu

Table of Contents

List of Figures

LIST OF TABLES

ACKNOWLEDGMENTS

This research was conducted under the Midwest Smart Work Zone Deployment Initiative (SWZDI) and Federal Highway Administration (FHWA) Pooled Fund Study TPF-5(081), involving the following state departments of transportation:

- Iowa (lead state)
- Kansas
- Missouri
- Nebraska
- Wisconsin

The authors would like to express their gratitude to the FHWA, the Iowa Department of Transportation (DOT), and the other pooled fund state partners for their financial support and technical assistance.

BACKGROUND

Work zones by nature present transitions and changes to motorists' expectations. Given these conditions, providing proper guidance to motorists is critical.

With respect to pavement markings, the challenge is to provide sufficient markings but in a temporary setting. Various pavement-marking products are currently in use within work zones; however, their effectiveness and cost can vary widely.

OBJECTIVE

This research evaluated the effectiveness of several common removable pavement marking products in terms of daytime presence, retroreflectivity, and removability.

METHODOLOGY

The work zone pavement marking evaluation was organized into three tasks as follows:

- Work with industry to identify the available products specific to removable tapes having a wet night retroreflective and/or wet recoverable feature
- Acquire these products and coordinate installation with a local contractor for a central Iowa work zone
- Monitor and measure performance in terms of durability (presence and retroreflectivity) and removal

The pavement marking evaluation was completed on an active work zone in central Iowa with the roadway setting and performance duration defined by the project. The desire was to select a project that would leave the markings in place for at least 30 days and have sufficient average daily traffic to provide an evaluation of wear. The evaluation included both white and yellow edge-line markings within the taper and crossover sections of a work zone.

Performance was measured in terms of presence, retroreflectivity, and ease of removal. Presence was evaluated in terms of the amount of product remaining at the end of the evaluation period. Retroreflectivity was measured using a 30 meter geometry retroreflectometer. Product removal was evaluated in terms of internal tape strength, adhesive bond, and the amount of discernible markings after removal based on the American Association of State Highway and Transportation Officials (AASHTO) National Transportation Product Evaluation Program (NTPEP).

LITERATURE REVIEW

Purpose

One common task in highway construction is placing temporary pavement markings on the construction lanes to provide safe navigation of motorists during a project. Safe navigation of motorists through the work zone is also important for the safety of the construction crew.

Work zones, with alignments and structures different from typical highway segments, bring with them higher crash risks. The differences in alignments, lighting conditions, and construction activities may distract motorists as they pass through a work zone. Therefore, providing clear and adequate pavement markings through the duration of a project is critical.

While safety is the main concern, another aspect of providing temporary pavement markings is finding the suitable material for the project. Four of the most common pavement marking materials used in work zones are water-based paint, thermoplastic, tape, and buttons. These materials cost and perform differently under different conditions and over different project durations.

Work zone pavement markings should be cost-effective, suitable to the traffic conditions, pavement surface, and weather conditions, have good nighttime visibility, and perform well through the project duration [1-3]. Ease of removal is another important criterion and is discussed later in more detail. Due to the variability in a range of factors that may influence performance, selection of a suitable pavement marking material for a project is a challenging task.

Retroreflectance

The visibility of pavement markings at night is provided by retroreflection, where the optics within the pavement marking reflect the headlight illumination back to the driver [2]. Under continuous wetting conditions, such as rain, the retroreflectance performance can diminish substantially. This degradation is partly due to loss of reflection from the water layer that covers the pavement marking optics, and partly due to the change in optical efficiency from the same water layer.

Retroreflectance performance of marking technologies differs. How a particular material performs during nighttime and under wet conditions is an important criterion as an agency selects among alternative temporary pavement marking materials.

Minimum retroreflectivity requirements for white and yellow markings are specified in Iowa Department of Transportation (DOT) guidelines as shown in Table 1 [4].

Table 1. Expected initial retroreflectance luminance (RL) under dry, wet, and rainy conditions*

WHITE	**Dry, Wet, & Rainy**
Entrance Angle	88.76 degrees
Observation Angle	1.05 degrees
Retroreflected Luminance R_L [(mcd • ft^{-2}) • fc^{-1}] (R_L [(mcd • m^{-2}) • lx^{-1}])	150
YELLOW	**Dry, Wet, & Rainy**
Entrance Angle	88.76 degrees
Observation Angle	1.05 degrees
Retroreflected Luminance R_L [(mcd • ft^{-2}) • fc^{-1}] (R_L [(mcd • m^{-2}) • lx^{-1}])	100

* Table 09012.02-1[4]

Removal Issues

When water-based paint and thermoplastic are removed mechanically by water blasting, flailing, milling, or grinding, a "ghost" marking often remains on the pavement due to the grinding of the pavement surface. Mechanical removal methods are expensive and leave scars, which can be mistaken for real pavement markings under wet conditions, nighttime, or when the sunlight hits the pavement at a right angle [5]. It takes approximately six months for the scarred pavement surface to blend with the rest of the concrete [3].

The Iowa DOT recognizes this problem and in related guidelines requires pavement markings to be removable "from the pavement intact or in large pieces, at temperatures above freezing without the use of heat, solvents, grinding, or blasting; and with no permanent scarring of the roadway surface" [4].

Using removable tape markings is a practical solution and a newer technology that eliminates the scarring issue from the temporary pavement markings. This project evaluated alternative removable tape marking technologies to provide guidance in selection for different work zones.

Studies from Other States

Several studies in the literature looked into the selection of temporary pavement markings in work zones or evaluated the performance of alternative technologies. These studies are noted briefly in this section.

For a 2008 project funded by the Texas DOT (TxDOT) [3], interviews were conducted with TxDOT staff and consultants who design and implement temporary pavement markings. The interview results show that paint is used by 88 percent of the respondents, thermoplastic by 80 percent, preformed tape by 60 percent, and buttons and retroreflective raised pavement markers (RRPM) by 92 percent.

Because paint is less durable under high traffic volume, some districts switched to using thermoplastic, which lasts longer and is more expensive. Most districts use paint and

thermoplastic on interim layers of non-concrete surfaces, so that markings do not need to be removed. If paint or thermoplastic is used on concrete or the final layer of a non-concrete surface, it must be removed by flailing, blasting, or milling.

Preformed tape is used by 60 percent of the respondents; however, half of the respondents reported that it is seldom applied. It was found that tape typically comes up prematurely. The authors noted that it is important to consider the scheduling of the project when selecting temporary pavement marking materials and factor in the unexpected project delays.

An experimental study evaluated three optics-on-paint marking systems employing high-refractive index, dual-optics, and drop-on elements at night under dry, wet recovery, and rain conditions [2]. These three systems were compared with two commercially-available marking systems (glass beads-on-paint system and wet-reflective removable tape) as industry benchmarks.

In this study, 30 participants driving through simulated work zones viewed all of the marking types at night under all three weather conditions. The driver's task was to identify the direction of work-zone lane shift tapers delineated by the markings.

As a result, in wet recovery, all three prototype marking systems and benchmark wet-reflective tape sustained 50 to 80 percent of their dry average detection distances in wet recovery and rain. However, the comparable detection distances for the conventional glass beads-on-paint benchmark system dropped to as low as 17 percent of the dry detection distance.

In a recent study, Songchitruksa et al. [1] provided a cost-based approach for selecting pavement marking materials for work zones. Monte Carlo simulation and sensitivity analyses were conducted given a set of factors influencing the performance of four types of marking materials, which were paint, thermoplastics, temporary tapes, and traffic buttons.

Based on the analysis results, the authors suggested use of traffic buttons at shorter phase durations and moderate traffic levels on the concrete surface. The use of thermoplastics was recommended as the lowest-cost alternative only on the asphalt surface with moderate project durations and traffic levels. Paint markings were recommended for short-duration projects regardless of traffic conditions or pavement surfaces.

Cost of removal and wet retroreflectivity performance of alternative marking types were not considered in this study.

EVALUATION

Products

The research team worked with industry and the Iowa DOT to identify products of interest for the field evaluation. This effort focused on removable tapes commonly used in work zones. At the time of this project, the Iowa DOT marking policy required that pavement marking tape be used when transitioning traffic on permanent roadway surfaces (not on temporary pavement, such as in the crossover), as shown in Figure 1. All non-tape required areas require paint.

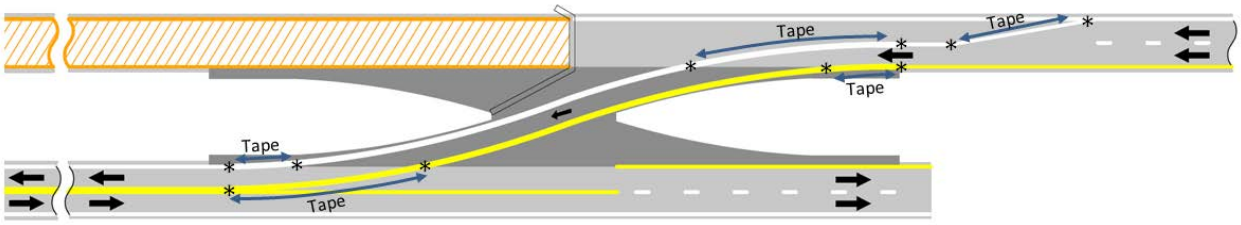

Figure 1. Iowa DOT required pavement marking tape locations

The research team identified three removable tape products to be evaluated as shown in Figure 2.

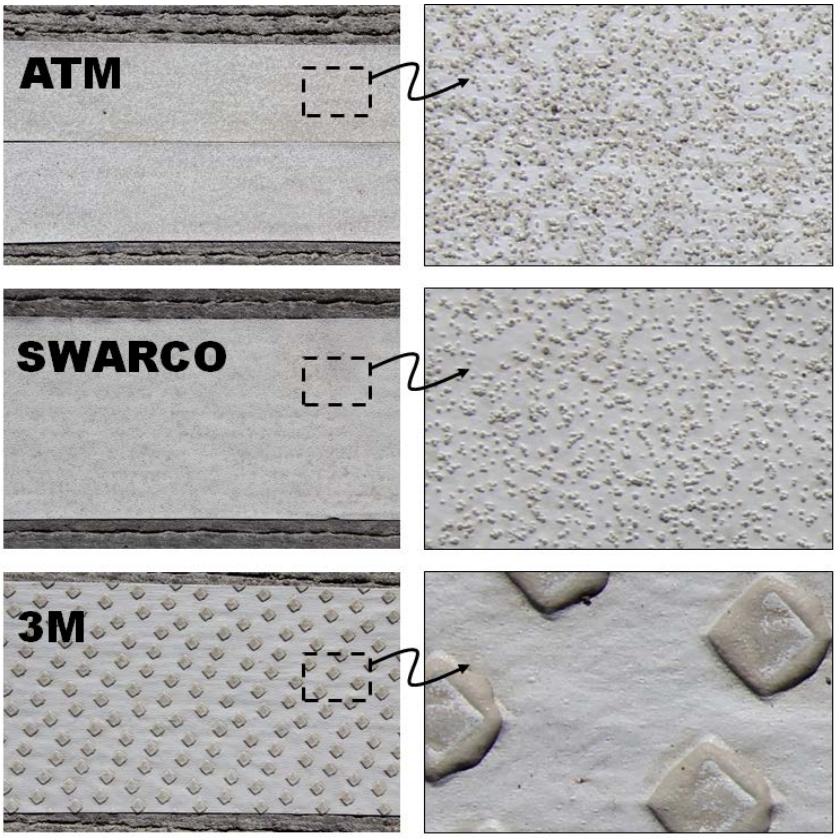

Figure 2. Temporary pavement marking tapes evaluated (white shown)

The following tapes were evaluated:

- Advance Traffic Marking ATM-200 Construction Tape – typically the default tape used by local area contractors for work-zone markings where required
- SWARCO Temporary Pavement Marking Tape D2 and D2-WR (wet reflective)
- 3M Wet Reflective Removable Tape Series 710

Each tape product was acquired in both yellow and white colors; however, no yellow ATM tape was installed due to the short quantities placed. The work-zone markings were to be 8 in. wide. The ATM tape was supplied at 4 in., so the material was installed in parallel to provide sufficient width.

Removable traffic paint was applied 8 in. wide where tape was not required, as shown in Figure 1. The benefit of the removable paint was that it could be removed easily with water as opposed to more abrasive removal methods, which tend to scar the pavement.

The material used was manufactured by Enventiv and labeled "GuideLine Removable, Water-based Traffic Paint (White) patent pending." The product is removed by applying a "remover" liquid, which neutralizes the paint over several minutes. After this, the paint swells and breaks apart and the materials are removed with a pressure washer.

Installation

A work zone on US 30 in central Iowa was used as the test location. This work zone supported rebuilding US 30 in the westbound direction at X Avenue (Exit 142) through closing the westbound lanes and transition to head-to-head traffic. Figure 3 provides an aerial photograph of the work zone. The posted speed of 65 mph was reduced to 55 mph at the beginning of one lane for westbound travel. The average annual daily traffic for this section of US 30 is approximately 13,600 vehicles per day.

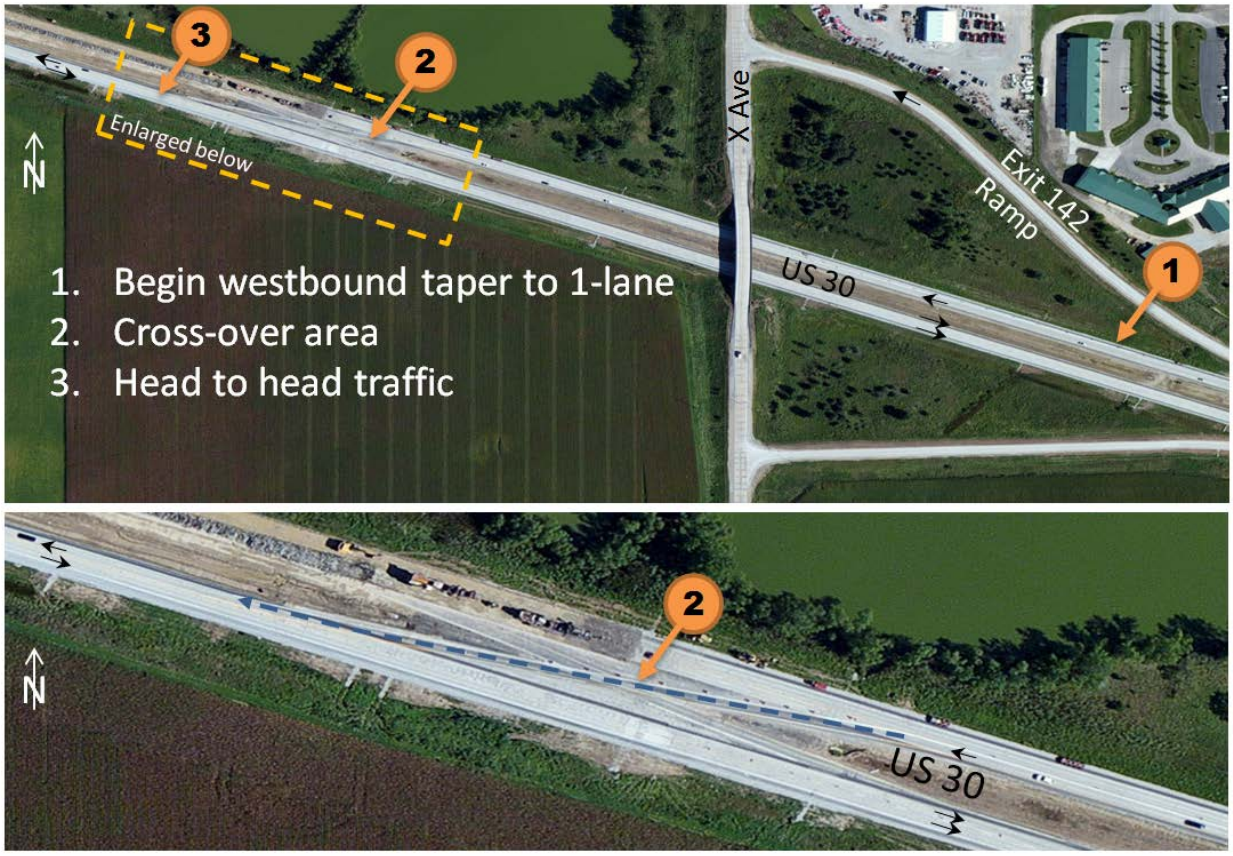

Figure 3. Work zone location and features

All pavement marking products were evaluated in the westbound direction of travel. A physical description of the work zone area includes a taper for westbound motorists from two to one lane immediately west of Exit 142 using a roughly 900 ft taper, which was followed by a 900 ft single westbound lane section prior to reaching the crossover. The crossover then served to transition into one lane each way on the south side of the US 30 median.

Product Placement

The three tape products and paint were installed on August 25, 2011 by an Iowa DOT contractor (Figure 4). The first step was to remove the existing painted lines in areas where pavement marking tape was to be installed; however, the existing markings were not removed in areas receiving new paint (painted over).

Figure 4. Installation images

The areas receiving pavement marking tape were divided up to accommodate the three products and the removable paint was applied at all other locations as shown in Figure 5. Figures 6, 7, and 8 show where the temporary paint and pavement marking tapes were installed within the work zone.

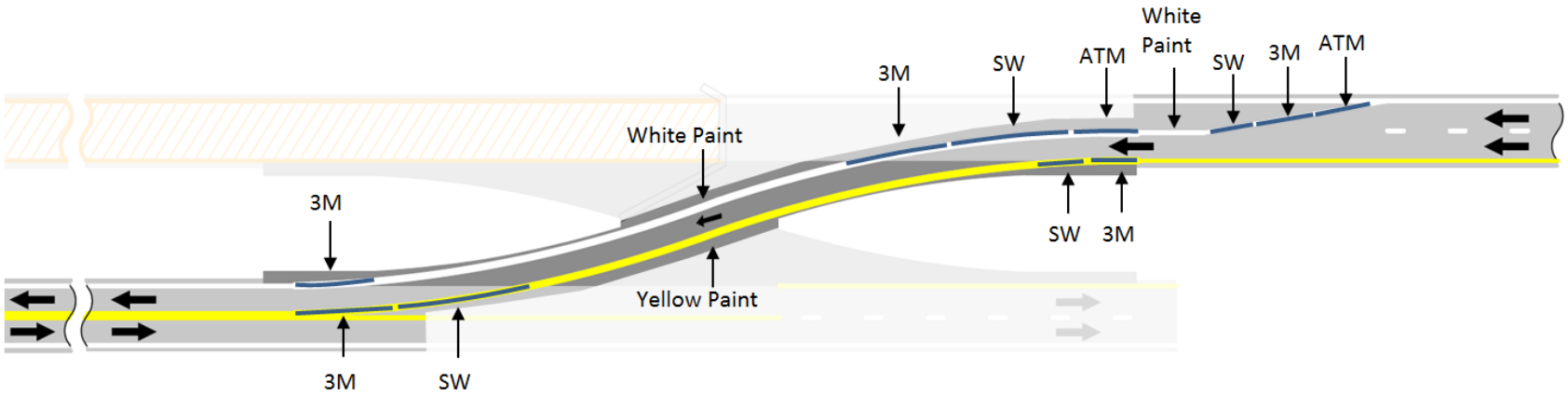

Figure 5. Installation locations by product

Figure 6. Product images within the taper section

Painted white right edge line.

This line was painted over existing yellow markings.

Visible material loss after 14 days.

Figure 7. White edge line between the taper and crossover areas

Figure 8. Tape products within the leading (left) and trailing (right) sides of the crossover

Field Performance

Each product was measured in terms of presence, retroreflectivity (dry), and removability. Table°2 shows the product evaluation timeline.

Table 2. Evaluation timeline

Stage	Date	Days after Installation
Installation	August 25, 2011	
Initial measurement	September 9, 2011	15
Final measurement	October 11, 2011	46
Removed	October 21, 2011	56

Presence

Removable Paint

Paint failures were observed at multiple locations. Just beyond the taper, the tangent white edge line, which was installed over an existing yellow line, began to show considerable loss after 15 days. Within the crossover, both the white and yellow markings became functionally obsolete within the first month and all were repainted using standard latex paint. Figures 9 and 10 show the paint loss within the tangent and crossover areas after 15 days.

Figure 9. Paint loss (white) after 15 days within the tangent (left) and crossover (right)

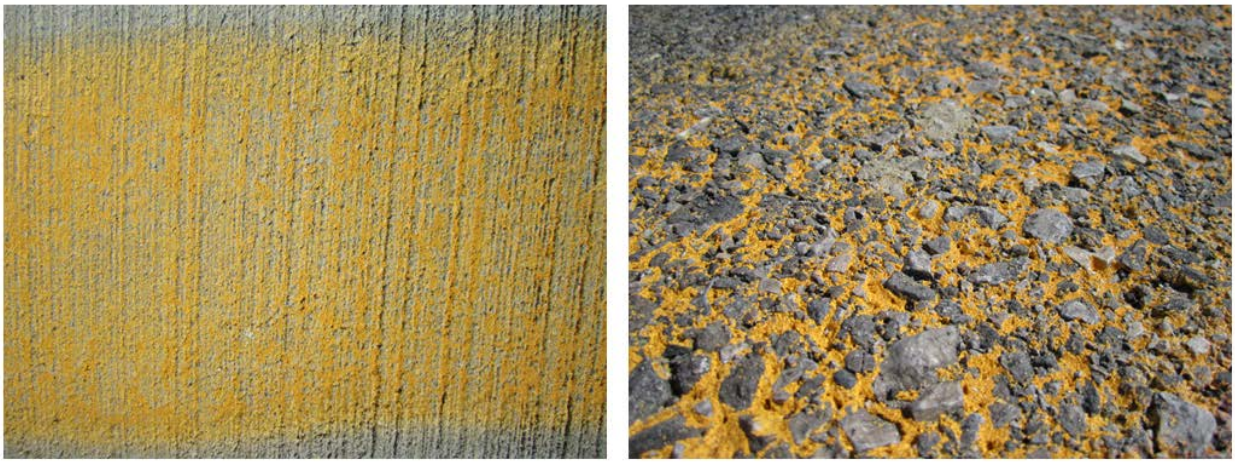

Figure 10. Paint loss (yellow) after 15 days within the crossover

Temporary Pavement Marking Tape within the Taper Area

The tape products installed within the taper did not show any visible wear due to traffic throughout the evaluation period. As shown in Figure 11, the majority of vehicles had already positioned themselves out of the closed lane and avoided these white edge lines, and adjacent traffic control drums, during their transition down to a single westbound lane.

Figure 11. Vehicle lane positioning away from the white edge line within the taper area

Temporary Pavement Marking Tape within the Crossover

The tape products installed within the crossover section experienced minimal to severe wear according to the location of the markings. As shown in Figure 12, when vehicles transitioned from the taper to the crossover (referred to within this report for clarity as the "leading" area of the crossover), drivers typically placed their vehicles over the yellow edge line, which caused heavy vehicle wear on these markings in contrast to the minimal wear on the white edge-line markings in this area.

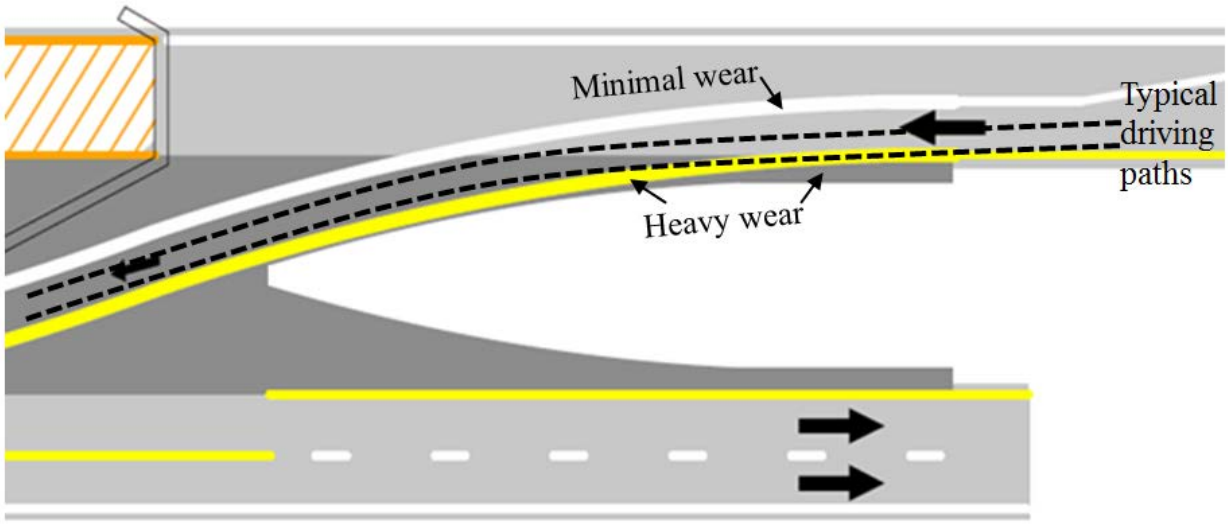

Figure 12. Typical lane positioning within the leading area of the crossover

Images of the wear to the yellow edge-line markings at the end of the evaluation period are shown in Figure 13.

Figure 13. End of project condition for yellow edge lines leading into the crossover

The temporary tape products installed on the trailing end of the crossover were subjected to considerable vehicle wear (yellow and white edge lines) as shown in Figure 14.

Figure 14. End of project condition for trailing edge-line markings

As shown, some sections of these edge-line tapes were installed over the existing rumble, which caused the tape to tear and deform.

Retroreflectivity

The field measurements of retroreflectivity were specific to each product and work zone section. Table 3 provides a summary of dry retroreflectivity readings measured using standard 30 meter geometry retroreflectometer in units of mcd/m^2/lux or commonly shortened to (mcd).

Table 3. Dry retroreflectivity readings

Product	Location	Line	@15 Days	@46 Days	@56 Days
ATM	Taper	White edge line	716	407	NA
3M	Taper	White edge line	695	362	NA
SWARCO	Taper	White edge line	333	284	NA
Paint	Tangent	White edge line	398	NA	NA
ATM	Cross-over (leading section)	White edge line	767	NA	NA
SWARCO	Cross-over (leading section)	White edge line	280	NA	NA
3M	Cross-over (leading section)	White edge line	445	NA	397
3M	Cross-over (leading section)	Yellow edge Line	447	NA	290
SWARCO	Cross-over (leading section)	Yellow edge Line	421	NA	267
Paint	Cross-over	White edge line	281	NA	NA
Paint	Cross-over	Yellow edge Line	34	NA	NA
3M	Cross-over (trailing section)	White edge line	548	NA	NA
SWARCO	Cross-over (trailing section)	Yellow edge Line	624	NA	507
3M	Cross-over (trailing section)	Yellow edge Line	382	NA	238

Retroreflectivity readings were not repeated in the exact same locations over time. Each installed product, other than the removable paint, still met Iowa DOT minimum retroreflectivity standards for both white and yellow markings at the end of the work zone stage (56 days).

Where no data exists, retroreflectivity readings were not available due to a combination of issues including the nature of the construction work zone activities, marking damage or wear, contamination, and, in the case of the taper, product removal prior to the scheduled time.

As an example, no data exist at the end of the evaluation period for the 3M white edge line located on the trailing end of the crossover. This marking had completely conformed to the underlying rumble strip and, in addition to this obstacle, it was not possible to obtain representative readings given the difference in elevation between the pavement and shoulder edges (Figure 15).

Retroreflective measurements for the temporary paint within the taper and crossover sections were not possible beyond the initial period, given that these had to be repainted using a different material approximately 30 days into the project.

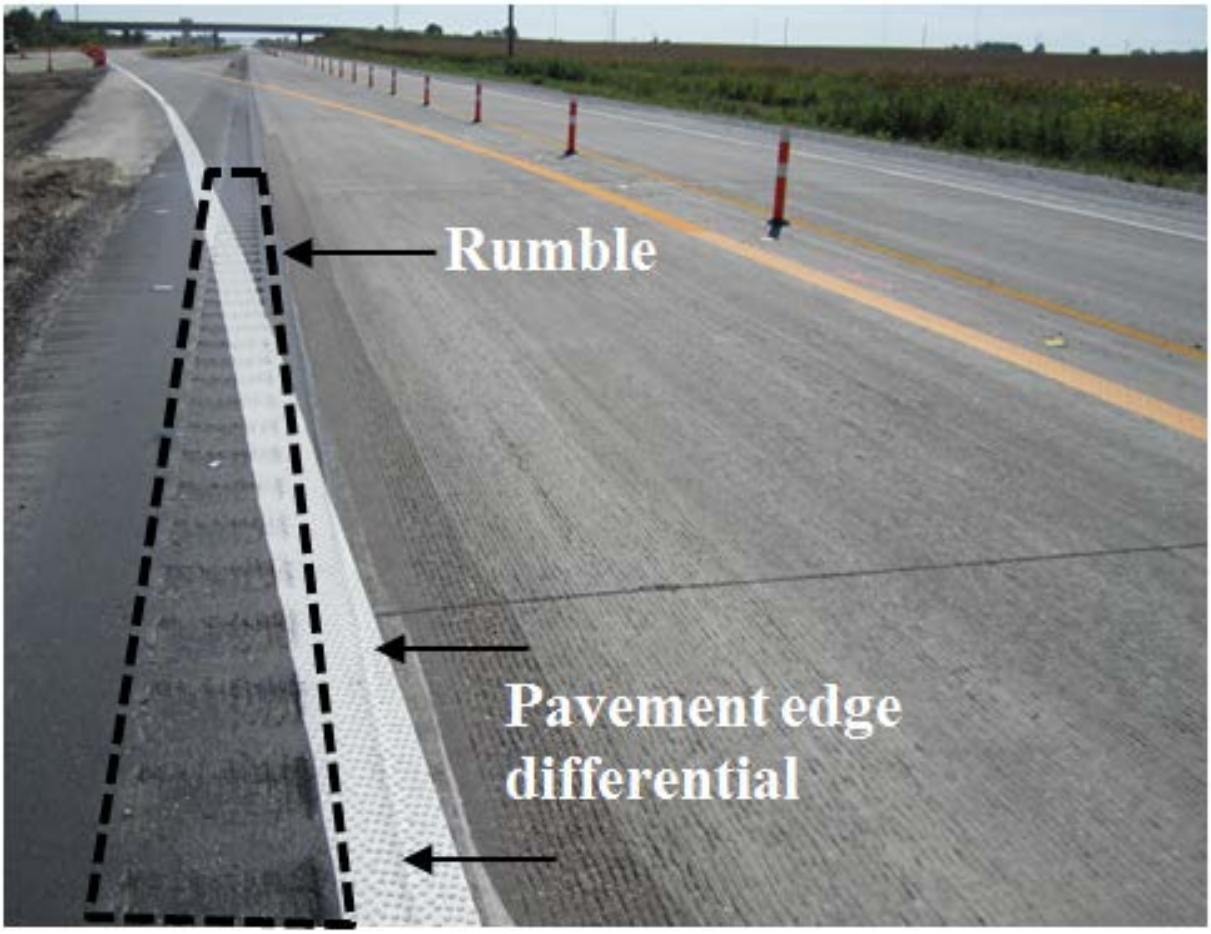

Figure 15. White edge line along the trailing end of the crossover

Removability

The ability to remove each tape product from the pavement was rated at the end of the project (56 days after installation) based on NTPEP *Field Testing and Evaluation Procedures for Temporary Pavement Marking Tape (revised August 2008)*. The ratings were completed for each installed marking by product, line type, and placement location within the work-zone area. It should be noted that products within the crossover area were installed over a variety of surfaces (asphalt cement concrete/ACC and portland cement concrete/PCC) and conditions (shoulder with rumble and pavement edge differentials).

Figure 16 shows a yellow edge-line product being removed from a smooth ACC shoulder, which had existing paint (left photo) and a white edge-line product being removed from a combination of PCC and rough ACC shoulder, which has a rumble (right photo).

Figure 16. Marking removal from a variety of surfaces

Temporary markings placed within areas that were driven over consistently were found to be much more difficult to remove, given the markings' conformity to the driving surface. Figure 17 illustrates how the markings conform to the PCC tine marks within the driving surface (left photo) and within the ACC rumble (right photo).

Figure 17. Marking conformity to the driving surface

The level of effort to remove each marking was rated and found to vary considerably. The top two photos within Figure 18 shows two examples of markings that were more difficult to remove for a yellow edge line on smooth ACC shoulder (left photo) and white edge line on PCC driving surface (right photo).

Figure 18. Variety in effort required to remove tape products

The lower two photos within Figure 18 show products that were much easier to remove for a yellow edge line on PCC (left photo) and white edge line on PCC (right photo).

The ability to remove each tape product from the pavement was rated on a scale of 1 to 10, as shown in Table 4, for the following:

- How many pieces had to be removed for complete removal (Internal Tape Strength)
- How much effort was required to remove tape (Adhesive Bond)
- Discernible markings after removal (Rating)

As shown in Table 4, internal tape strength was found to be consistently rated as a 1 (tape removed intact, in one piece) except in high traffic areas where a rating of 5 was given to the 3M yellow edge line and a rating of 10 (tape only removed in very small fragments) was assigned to the 3M white edge line, which had completely conformed to the shoulder rumble.

Table 4. Removability rating by product

Product	Location	Line	Within Wheel Paths	Internal Tape Strength	Adhesive Bond	Discernible Marking After Removal
ATM	Taper	White edge line	Min	1	2	6
3M	Taper	White edge line	Min	1	4	3
Swarco	Taper	White edge line	Min	1	1	3
ATM	Cross-Over (leading section)	White edge line	Min	1	3	2
Swarco	Cross-Over (leading section)	White edge line	Min	1	1	1
3M	Cross-Over (leading section)	White edge line	Min	1	5	3
3M	Cross-Over (leading section)	Yellow edge line	Max	5	9	Over existing white paint
Swarco	Cross-Over (leading section)	Yellow edge line	Max	1	2	Over existing white paint
Swarco	Cross-Over (trailing section)	Yellow edge line	Max	1	2	0
3M	Cross-Over (trailing section)	Yellow edge line	Max	1	9	3
3M	Cross-Over (trailing section)	White edge line	Max	10	10	NA

How many pieces had to be removed for complete removal (Internal Tape Strength)?
Internal Tape Strength (Rating):
1 = Tape removed intact, in one piece
3 = Tape removed in three to four pieces
5 = Tape removed in five pieces
7 = Tape removed in seven pieces
10 = Tape only removed in very small fragments

How much effort was required to remove tape (Adhesive Bond)?
Adhesive Bond (Rating):
1 = Tape removed easy (potentially by one hand)
3 = Tape removed with moderate, two-handed effort
5 = Tape removed significant, two-handed effort, requiring multiple pulls
9 = Tape removed only by exhausting, two-handed effort
10 = Tape could not be removed from surface

Discernible Markings after Removal (Rating)
Discernable Marking (Rating):
1 = No discernable marking on road surface
5 = 50 % of marking (adhesive outline) left on road surface
10 = 100% of marking left on road surface

Adhesive bond varied among products (rated from 1 to 10) and again appeared to be most influenced by high traffic wear. The degree of discernible marking after removal varied in rating from 1 to 6, where the ATM white edge line within the taper had a discernible presence of adhesive left on the road surface.

CONCLUSIONS

This project evaluated three temporary pavement marking tape products and a removable paint over a 56 day time period. The products were strategically placed within sub-areas of a work zone to evaluate performance over time in terms of presence, retroreflectivity, and removability.

The temporary pavement marking tapes performed satisfactorily over the 56 day time period with the exception of materials placed over very rough surfaces (rumble strip) or where vehicle maneuvering directly over the marking led to tearing or similar damage.

The removable paint failed after 15 days and was repainted using a latex paint. The new latex paint used to restripe these areas provided minimal guidance (within the crossover) by the end of the work zone stage.

The tape products used at the leading and trailing ends of the crossover were subjected to heavy traffic use, yet performed significantly better than the painted markings. All tape products met the Iowa DOT minimum retroreflectivity standard throughout the duration of the work zone. With a few exceptions, due to marking location, the tape products were removed easily with minimal to moderate discernible markings remaining.

Temporary pavement marking tapes are a more expensive alternative to latex paint for providing pavement marking guidance within a work zone. Some agencies allow the use of these tapes on permanent pavement surfaces but not on temporary surfaces, as is the case with the paved cross-over area within a median. These policies can vary but often show a preference to use the tapes where the work zone transitions on permanent pavement surfaces, as it minimizes scarring once the markings are removed. To save money, the tape products are not allowed within the temporary cross-over areas where there is no incentive to worry about pavement scarring once the markings are removed. This limited study observed that from a durability perspective, the use of temporary tape products should be considered within the cross-over areas of a work zone given their superior performance, in terms of both presence and retroreflectivity, over traditional latex paint products.

RECOMMENDATIONS

Based on these findings, the research team recommends the following:

1. Agencies who are not currently specifying the use of temporary pavement marking tape products on temporary roadway surfaces (eg. within the cross-over area of a work zone which will be removed after the project) should reconsider their policy. The cross-over area receives the majority of wear, due to traffic weaving, and these markings are placed over a variety of, smooth to very rough, pavement surface conditions.

2. Removable paint products are rapidly evolving and are a potentially promising alternative in terms of installation, cost, and removal (no scaring) which should be further investigated.

REFERENCES

1. Songchitruksa, P., G. L. Ullman, and A. M. Pike, "Guidance for Cost-Effective Selection of Pavement Marking Materials for Work Zones." *Journal of Infrastructure Systems*, 2011. 17: p. 55.
2. Higgins, L., J. D, Miles, P. J. Carlson, D. M. Burns, F. Aktan, M. Zender, and J. M. Kaczmarczik. The Nighttime Visibility of Prototype Work Zone Markings Under Dry, Wet, and Raining Conditions. Transportation Research Board, 88th Annual Meeting. 2009. Washington, DC.
3. Ullman, G. L., M. D. Finley, A. M. Pike, K. K. Knapp, P. Songchitruksa, and A. A. Williams. *Studies to Improve Temporary Traffic Control at Urban Freeway Interchanges and Pavement Marking Material Selection in Work Zones*. Research Rep. 0-5238-2, Texas Transportation Institute, College Station, TX, 2008.
4. Iowa DOT. *Supplemental Specifications for Wet Retroreflective Removable Pavement Markings*, SS-09012, 2010.
5. Ellis, R. *Development of Improved Procedures for Managing Pavement Markings During FDOT Highway Construction Projects*, Final Report, 2003.